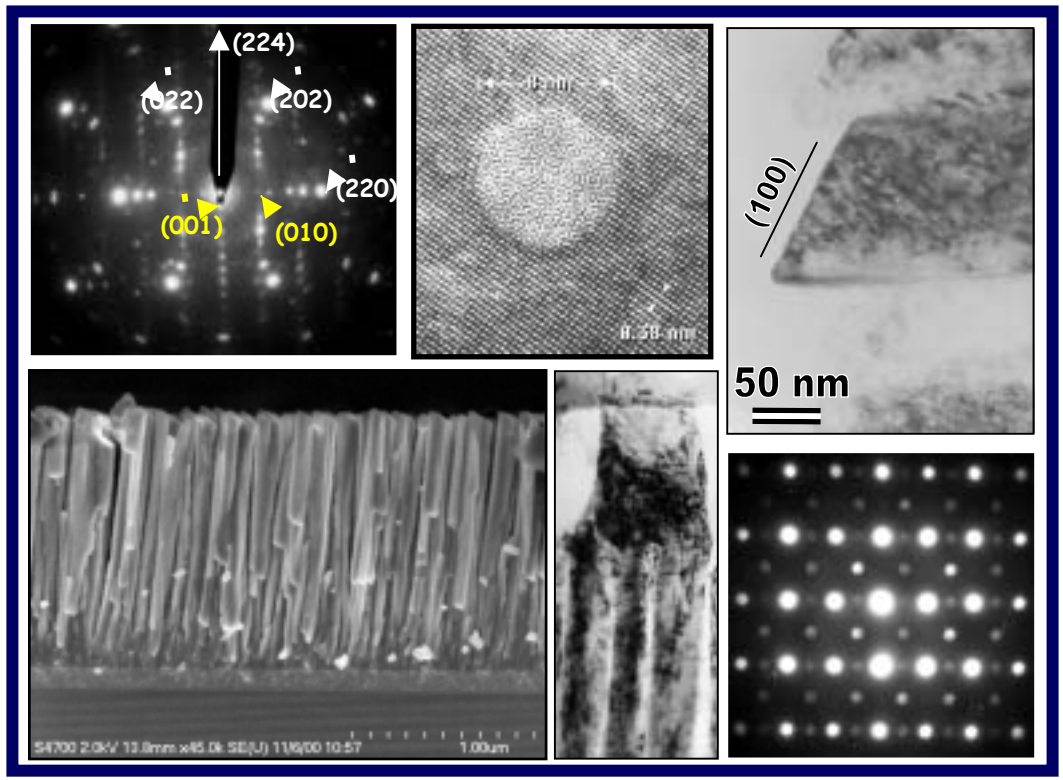
Characterization of Coated Conductors by Electron Microscopy/Microanalysis



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2003 Wire Development Workshop, St. Petersburg, FL, January 21-22, 2003

Electron Microscopy and Microanalysis

Methodologies used to determine the structure of matter, in this case using electrons.

Why is electron scattering so useful ???

- many signals (strong interactions with both electrons and nuclei)
- exceptional resolution (very short wavelengths)
- high source brightness
- readily focused (can form images; probes $\leq$ 0.1 nm for scanning)

Well suited for coated conductor characterization:

- morphology & microstructure
- crystallography, atomic structure, interfaces
- elemental/chemical composition
- grain-to-grain correlations & texture

EM as part of the characterization "team"

Highly complementary to other microscopies (scanning probes, Raman, MOI, optical), x-ray diffraction

Special role for electron microscopy: spatially correlated data with very high spatial resolution

In many situations, can avoid or minimize global averaging

- "spot" mode analysis - study a given region in detail
- images ("maps") of pertinent data:

  crystal orientation, composition, phase, etc

Electron microscopies: TEM & SEM

Scanning electron microscopes (SEM):

+ often no sample preparation, relatively fast analysis
+ good spatial resolution to ≈1nm

- data not as comprehensive as TEM
- precise chemical information only at larger length scales
- limited info on crystal structure

Transmission electron microscopes (TEM, STEM):

+ extremely rich data
+ outstanding spatial resolution for ≈all forms of data possible

- time-consuming data acquisition & analysis
- generally requires specially prepared samples (extremely thin)
- not all information accessible in same instrument w/ same sample

- In both TEM & SEM, ratherlimited *in situ* capabilities

Challenges in applying TEM to coated conductors

Speed (turn around time)

Statistics

Site specificity

- primarily influenced by challenging **specimen preparation**

Data collection & analysis are time consuming

Can we utilize effort more effectively to maximize impact and minimize effort spent on "routine" tasks???

Opportunities for improvement

Focus on specimen preparation - the biggest obstacle:

TEM specimen output tends to be low, slow

Most specimen preparation techniques require sample to be "destroyed"

Together, these issues compromise the impact of TEM feedback on processing

- generally one of last techniques applied
- sometimes a reluctance to give up samples for TEM

Increasing use & development of new instrumentation offers an opportunity: focused ion beam (FIB) methods

FIB as an R&D tool for coated conductors

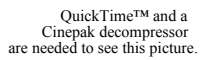
Focused ion beam instruments offer new capabilities & opportunities for TEM specimen preparation

- nanoscale "cutting tool" to extract specimens

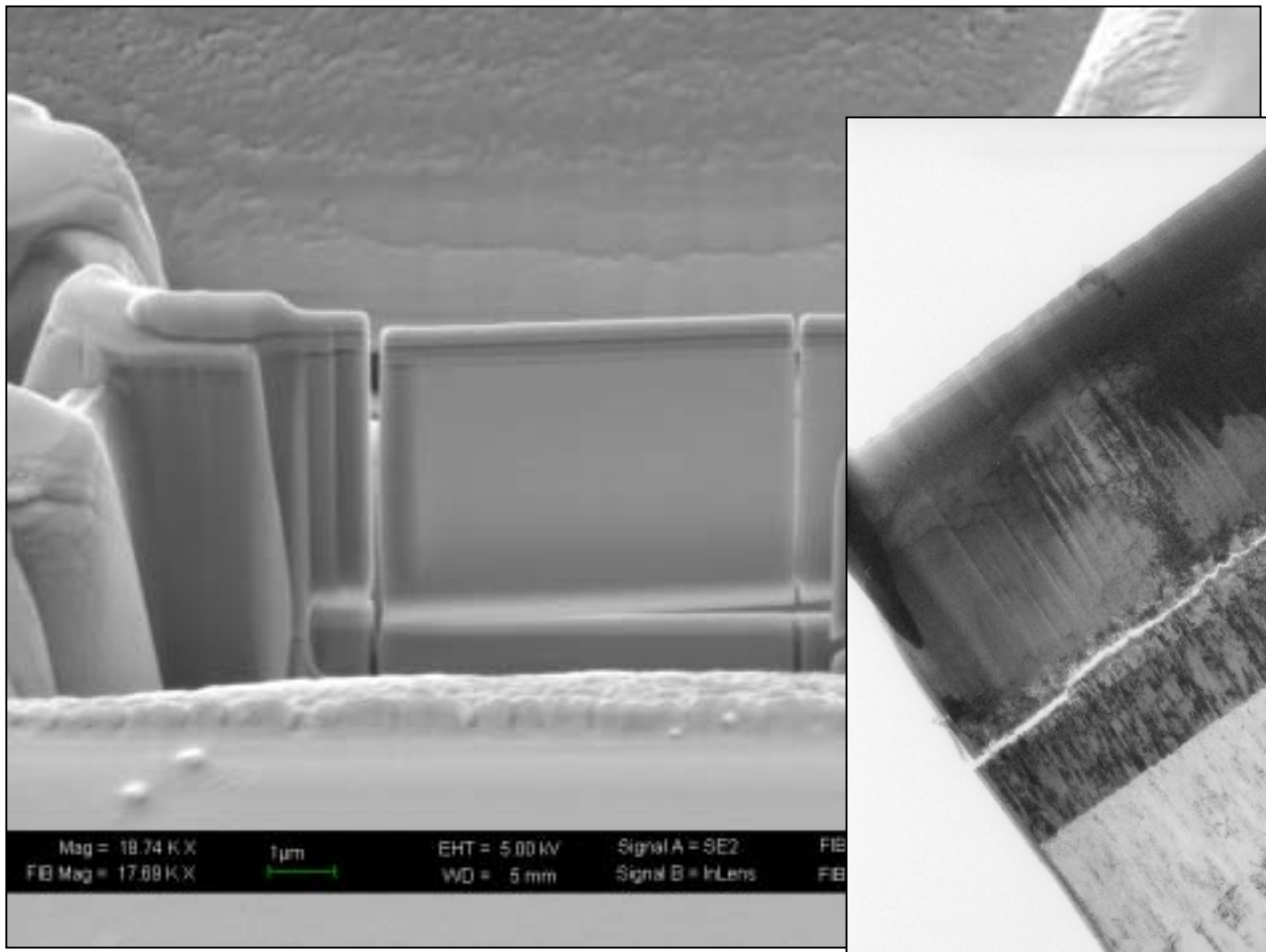
- Simultaneous imaging facilitates site-specific specimen preparation
- Automation increases efficiency of specimen prep
  - can speed turn around time for routine analysis
  - can make more specimens to improve statistics

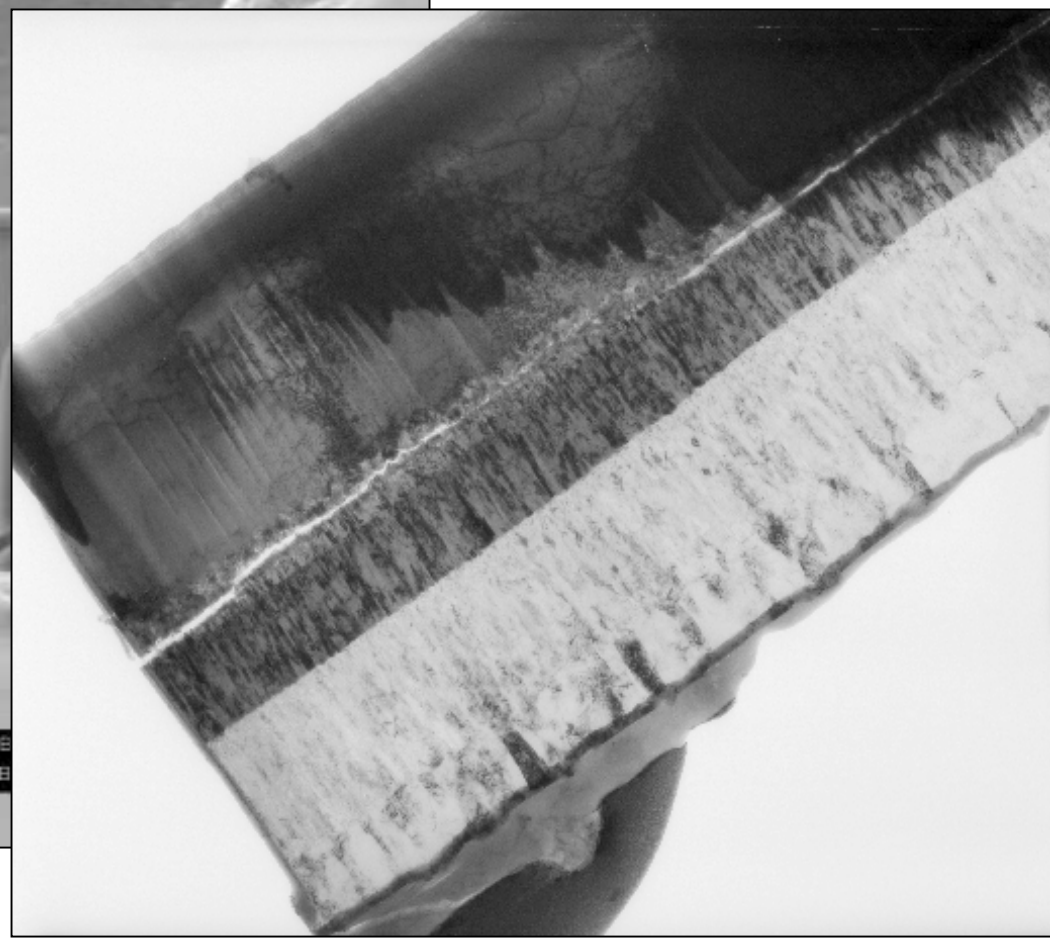
Precision sectioning & ability to deposit leads offers opportunities to improve other characterization approaches

FIB as an R&D tool for coated conductors



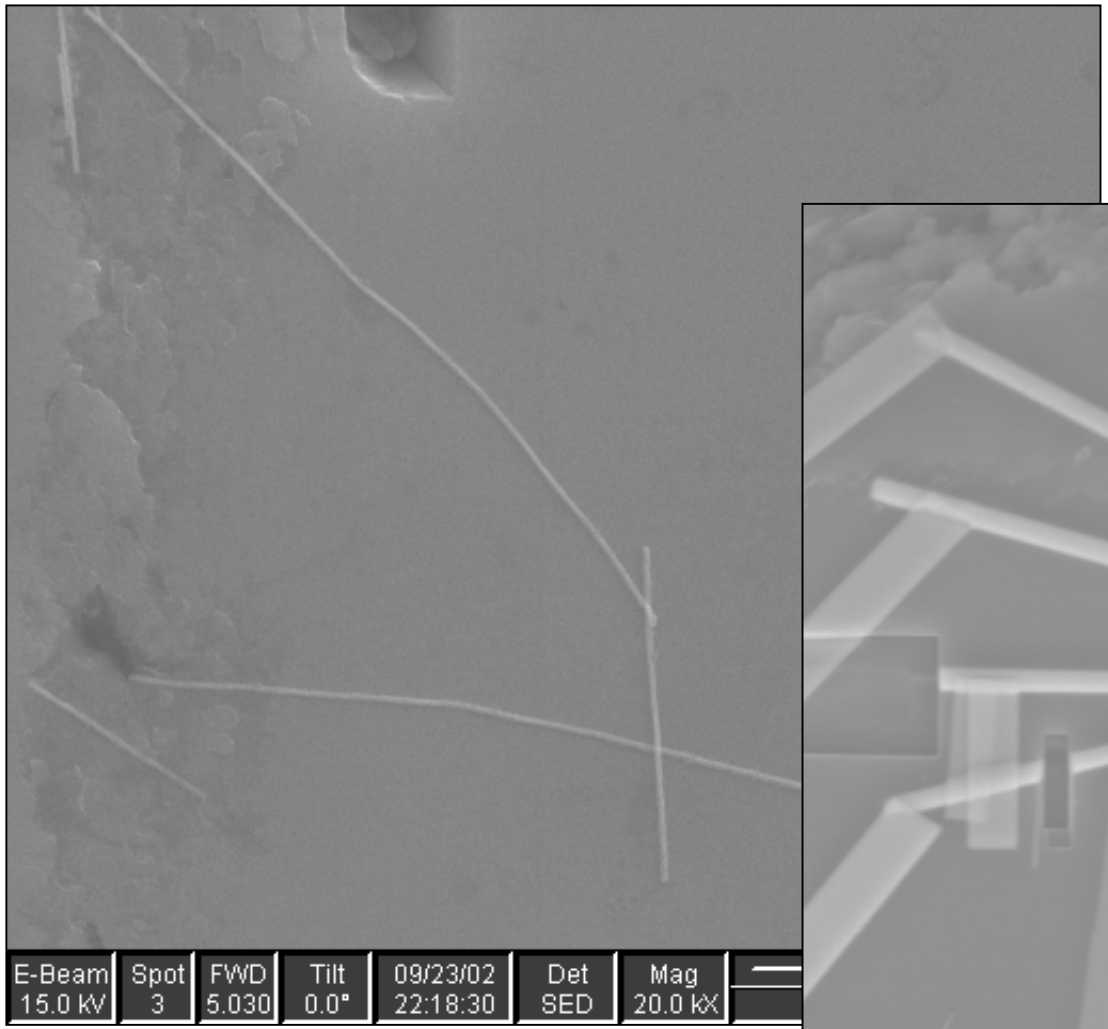
FIB as an R&D tool for coated conductors

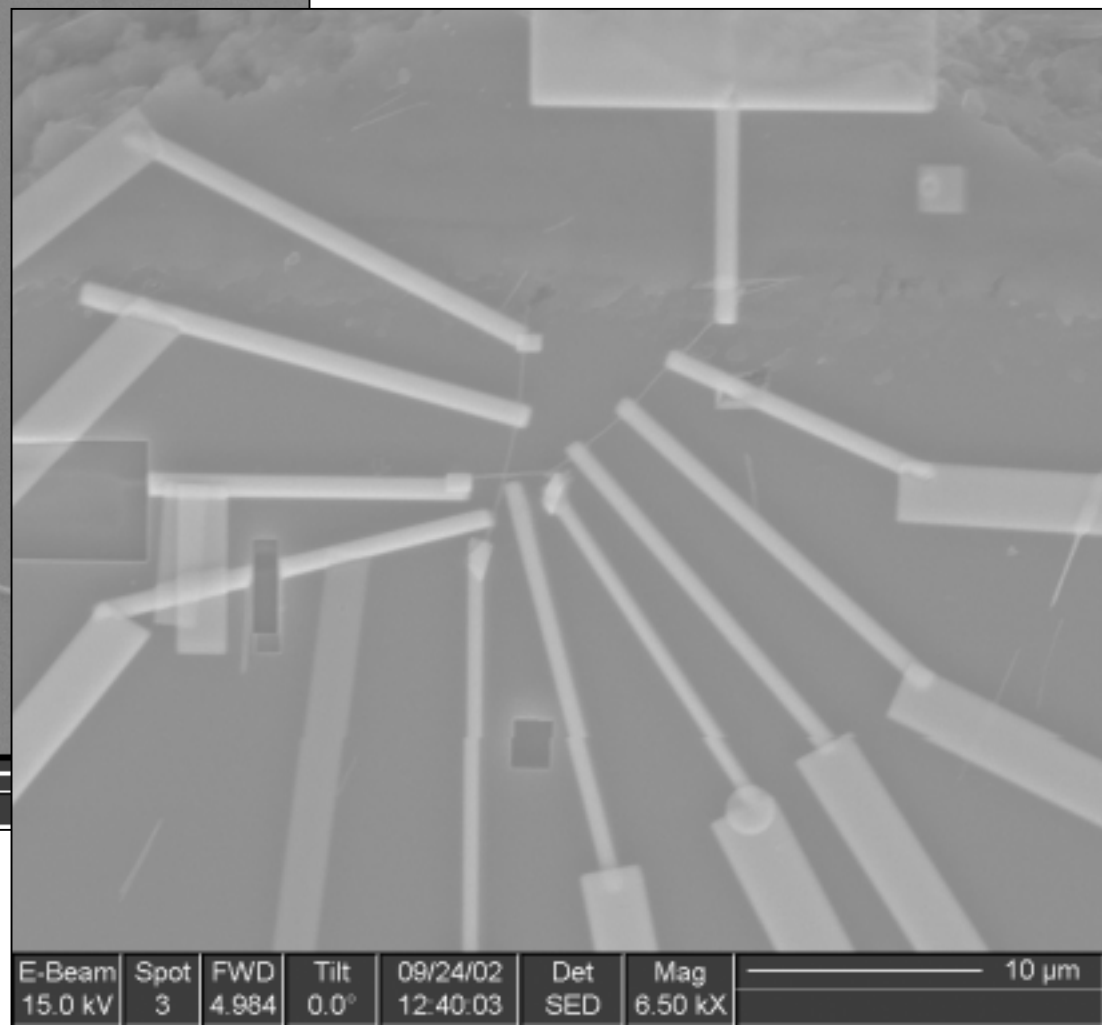




- site-specific sample prep
- amenable to automation

FIB as an R&D tool for coated conductors

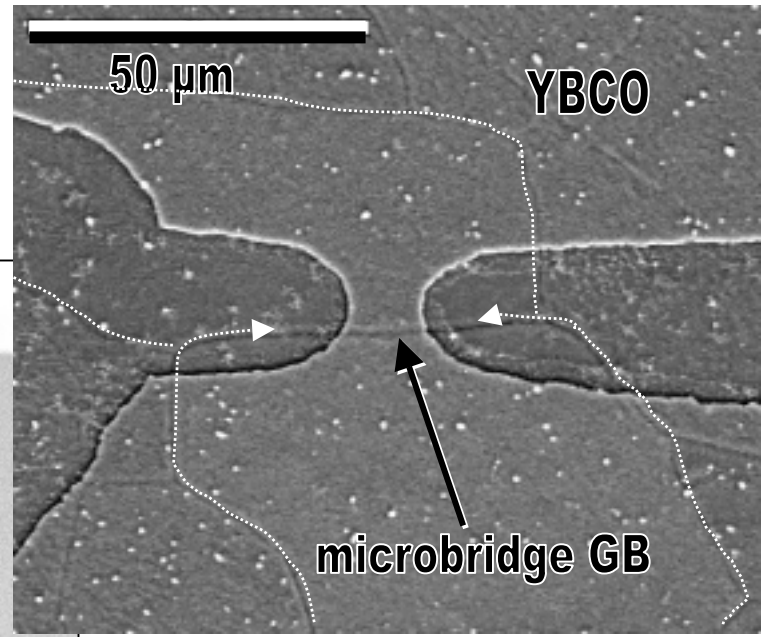


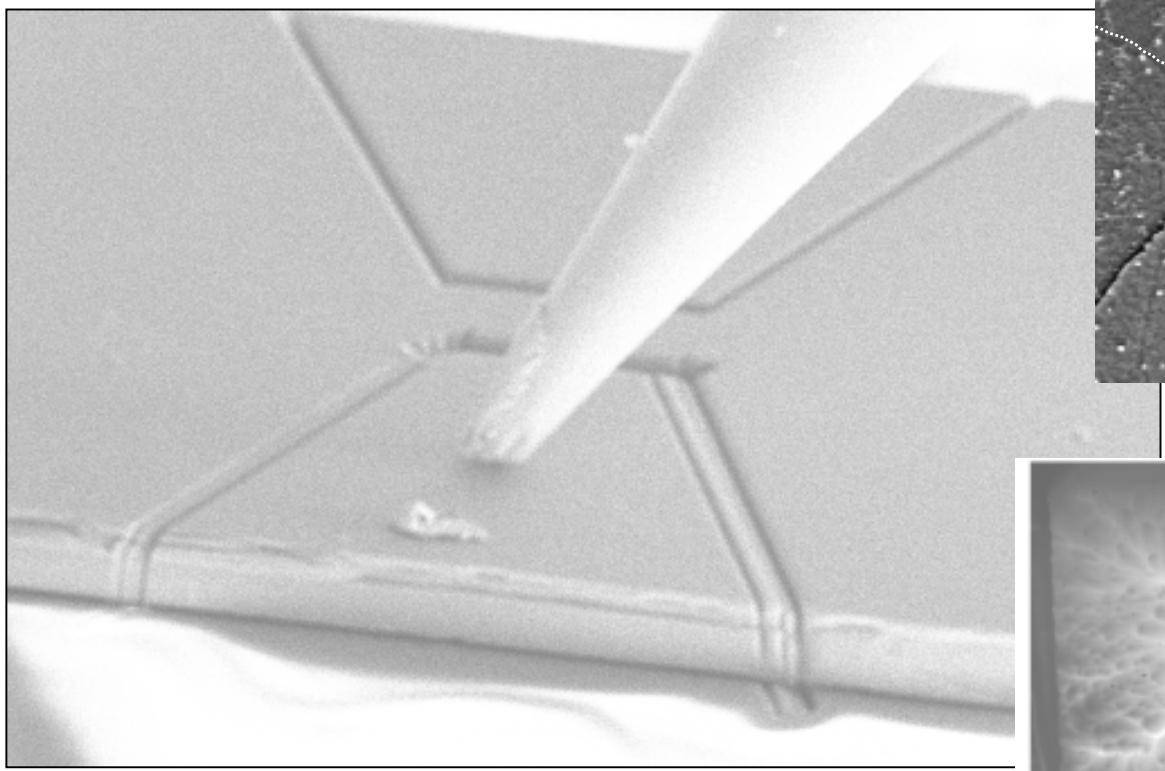


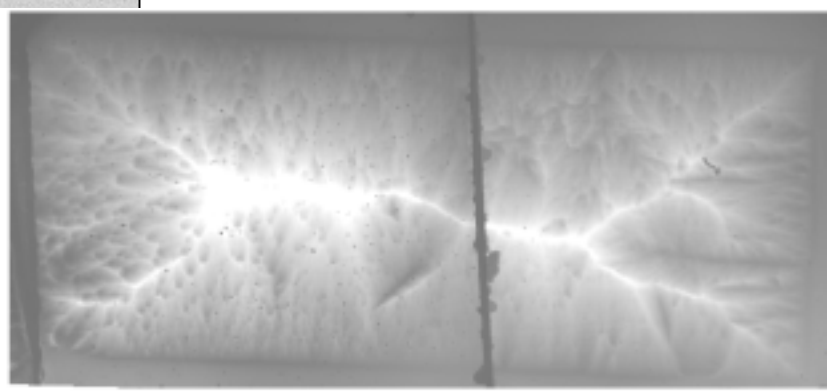
- wiring on the nanoscale

FIB as an R&D tool for coated conductors

- site-specific patterning
- together with wiring capability,
  offers many possibilities







MOI image, trapped field, 77K

EM in the Characterization of Coated Conductors

Electron microscopy plays a valuable role in providing high spatial resolution for imaging & spectroscopies

Providing data in a useful time-frame is challenging

+ new techniques and instrumentation offer great potential to improve this situation and can enhance capabilities for other analyses

Most lab-scale equipment meets the needs for characterization, but there are some limitations

+ new developments in aberration correction are leading to gains in instrumental capabilities

Morphology, crystallography, composition, orientation data from very small volumes

Focused probe measurements allow crystal structure, composition, orientation to be determined

- especially relevant for understanding nature of defects